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CHEMISTRY.—*Life without oxygen.*[1] W. MANSFIELD CLARK, Hygienic Laboratory.

In these days of overcrowded programs an investigator is given but one opportunity to read an essay. That is when his fellows, having retired him from their highest office, display their kindness, letting him down easily with assurances that they really wish a presidential address. It is assumed that a presidential address shall be more of the nature of an essay than a technical paper. Therefore I shall not expand the technical details of the studies on oxidation-reduction which you gave me an opportunity to outline last year, but shall discuss a subject of more popular interest toward the solution of which these technical studies can contribute.

Famine, religious fastings, and the hunger strikes of political prisoners have left records of men living without food for months. Tales of the sea, founded upon fact, have repeated the cry of the Ancient Mariner as day after day he fought thirst with "Water, water, everywhere, nor any drop to drink." To be without food and water for a few days is no great hardship according to the testimony of Stefánsson, but in contrast to this endurance of hunger and thirst is our incessant demand for oxygen.

In every physiological laboratory there is performed an experiment in which the subject rebreathes from a bag. Within a short time the oxygen in the bag is exhausted and to the satisfaction of the instructor and the delight of the students the subject faints. Haldane says that if the residual oxygen in the lungs be washed out with hydrogen, unconsciousness follows in 50 seconds.

[1] Presidential address, presented before the Chemical Society of Washington. January 11, 1924. Published by permission of the Director of the Hygienic Laboratory.

The sailor in his thirst cannot use the water of the sea because its partial pressure is too low for his physiology. A rough parallel is found in the experience of the balloonist. When he reaches high altitudes he finds oxygen still in unlimited quantity but at a partial pressure far too low. Witness the famous balloon ascension by Crocé-Spinelli, Sivel, and Tissander in 1875. At 24,600 feet with the barometer at 300 mm. Sivel obtained the consent of his companions to go higher. He unloaded ballast. They were provided with small supplies of oxygen but Tissander found his arms already paralyzed and could not take the mouthpiece of the oxygen bag. He saw the barometer pass 280 and then became unconscious. He later woke to find they were descending, and, with the cheerful optimism and self-confidence so dangerous in victims of anoxemia, he let go ballast and up they went again. Then the others woke and let go ballast. To all three came unconsciousness. When on the descent Tissander came to, he found both his companions dead. Their supplies of concentrated oxygen had been too small in the first place but they had become partly paralyzed before trying to use it.

The annals of adventure, war, murder, suicide, and persecution describe various crude or artistic methods of producing anoxemia, but a much more fascinating story is the development of an understanding of the manner in which the body supplies itself with oxygen.

In all science there are few developments as beautiful as that which has given us the present precise knowledge of the blood equilibria. There have been found: a quantitative relation between the iron of the blood pigment and the oxygen combining capacity; quantitative data for the equilibria between partial oxygen tensions and degree of oxygen saturation of haemoglobin; preliminary data on the Donnan equilibrium between the oxygen-carrying blood pigment, trapped within the semi-permeable membrane of the red cell, and the plasma; exact relations for the bicarbonate equilibria of the plasma and the acid-base properties of the oxygen carrier; the mechanisms for the maintenance of constant hydrogen ion concentration of the blood and the control of lung ventilation by the activation of a nerve centre called the respiratory centre. Of this Haldane says, "A rise of 0.2 % or 1.5 mm. in the CO_2 pressure of the alveolar air and arterial blood causes an increase of about 100% in the resting alveolar ventilation. The astounding delicacy of the regulation of blood reaction is thus evident. No existing physical or chemical method of discriminating differences in reaction approaches in delicacy the physiological reaction."

Now even ancient man recognized that air was essential to his own vitality. When Joseph Priestley discovered oxygen and Lavoisier named and correctly interpreted its function in the human body the world of thinking men soon came to realize that the life of a man hangs from moment to moment upon his ability to maintain intact the transport of the element oxygen between air and tissues. This is a fact; so are the great achievements in the science of respiration. Is it then any wonder that we who have made our gods in our own image should project this knowledge of our physiology, exclaiming, "There can be no life without oxygen"?

A prominent modern text on physiology opens with the statement, "*All* living things respire—that is they consume oxygen, liberate energy by combustion or oxidative changes, and they give off carbon dioxide." Because of that little word *all* every phrase of this statement is subject to challenge by the records of the literature.

The allegation of universal liberation of energy by combustion and production of carbon dioxide can be disposed of in a sentence. There are organisms which produce active metabolism without liberating CO_2, and there are CO_2 productions which have no relation to the consumption of molecular oxygen. To speak of CO_2 production as necessarily associated with respiration, as Osterhout does, is needlessly to confuse the whole subject by thoughtless definition.

As to the implied dependence on oxygen here are a few facts. As early as 1776 Spallanzani recorded organisms living under greatly diminished air pressure. Miall, in his *Natural history of aquatic insects*, remarks, "Either the storage capacity for oxygen in *Chironomus* larva is considerable or it must be used carefully, for the animal can subsist long without a fresh supply." A study of this problem was made by Leitch, who concluded from laboratory experiments that the storage capacity of the haemoglobin in the *Chironomus* larva is sufficient for at most 12 minutes of anaerobic life. The oxyhaemoglobin is quickly reduced in the mud where the organism is found. Cole confirms this by laboratory and field studies.

As we descend the scale of organized life we find adaptation to anaerobic conditions—that is, life without air—becoming more easy. Protozoa are found in stagnant waters and are parasites in the intestine where conditions are often anaerobic. Pütter kept *Opalina* alive for 20 days in a solution devoid of oxygen. *Opalina* is a genus found in the intestine of the frog. *Balantidium coli* is a closely related protozoon found in the intestine of man, where it and the tape worm must live an anaerobic life. Pütter, having investigated several other

protozoa, says, "Their widespread independence of free oxygen presents a close analogy to countless plants." Pütter kept starved leeches alive 15 days without air, and Bunge cultivated the vinegar eel, which we have all seen wiggling in corked bottles of vinegar, under laboratory conditions seven days without oxygen. In short, there is in laboratory experiments abundant evidence of anaerobiosis, even aside from plant life.

By reason of a fundamental ignorance of cultural conditions laboratory experiments are not entirely satisfactory for long continued experiments. It is, therefore, significant that anaerobiosis has been found under natural conditions.

Juday has reviewed the work on the lakes of Wisconsin, many of which undergo stratification at certain seasons, leaving the bottom water stagnant. Into this bottom water drop decaying materials which reduce the oxygen content so thoroughly that no trace of oxygen has been detected, either by direct gasometric analysis or by two titration methods. In mud taken from the bottom of Lake Mendota, at the University of Wisconsin, 11 genera of protozoa—in form perfectly normal—have been found in abundance. Three species of worms, a rotifer, one species of the crustacea, and one of the mollusca were found. This population was as abundant and as active in late September as in early October, that is, throughout the period of oxygen-lack; and to check against the possibility of temporary migrations from the mud into the upper surface layers of the lake, Juday collected the mud under anaerobic conditions, and observed the organisms in the laboratory. They remained active out of contact with oxygen.

Among the lower orders of true animals and among the protozoa it is evident that there can be anaerobiosis. Let us now turn to a more familiar field.

In 1861, Louis Pasteur read a paper before the French Academy, entitled *Little animals living in the absence of oxygen and bringing about fermentation.* It was a straightforward statement of observation. Organisms we now know as butyric acid bacilli were found moving actively and fermenting in cultures devoid of oxygen. Furthermore the entrance of oxygen stopped their movement and checked the fermentation.

Since this observation there have come to be known as anaerobes numerous bacteria, some of which are our friends and some of which are our deadly enemies. Since these bacteria display most clearly

the fact of anaerobiosis it is interesting to examine the methods of anaerobic culture.

There have been published at least 35 devices, making use of the replacement of air by hydrogen. As a substitute for hydrogen, CO_2, CO, coal gas, acetylene, steam, nitrogen, and argon have been used. At least 7 devices for absorbing oxygen within the medium, and 10 without the medium, exclusive of 41 devices for the use of pyrogallol, have been described. There is no essential difference *in principle* between protecting a culture from access of air by a cover of oil or by a deep layer of the medium, but 20 authors have described deep layers, 7 authors, covers of mica or glass, and numerous authors have tried almost every conceivable oil, and covers varying from agar to plasticine. At least 10 so-called new devices for vacuum cultivation are recorded, and no one knows the number of combinations.

Most of the principles embodied in the various published devices were used by Pasteur and his school, and we must not be deceived by the claims of originality. Rather is it our duty to brush aside the hundreds of papers on the subject and select the few which deal with the principles involved. I shall have time for only a brief review.

In 1877 Gunning, of Amsterdam, expressed his dissatisfaction with the current views of anaerobiosis. He maintained that in no case where bacteria had been observed to grow in what was alleged to be the complete absence of oxygen had adequate tests for the absence of oxygen been applied. Gunning mentioned the possibility of oxygen remaining loosely combined with the materials of ordinary media, the layer of condensed gas formed on glass surfaces, and the diffusion of oxygen through rubber and other connecting material. He reviewed some of the tests for oxygen which had been applied, gave evidence of their inadequacy, and took the stand that the best one can do is to rest on the statement that the method employed has given such and such evidence of low oxygen content—never that the total absence of oxygen has been insured. With ferro ferrocyanid Gunning obtained a reaction for oxygen in boiled water. For the absorption of dissolved oxygen he employed alkaline sugar and ferrous salt solutions, and applying his reagent to the sealed space above the medium, from which he had removed all the oxygen he could, he found no coloration. This indicated that he had obtained more complete removal of oxygen, with better assurance of the fact, than had those who employed the ordinary methods of anaerobic culture. Gunning then applied his methods to actual cultural inves-

tigations, and reported that as the removal of oxygen was made more and more complete the action of bacteria dwindled to almost negligible proportions.

This attack upon the accepted views of bacteriologists drew the fire of Nencki, who emphasized the fact that Gunning had worked with mixed cultures and had taken no care to insure the presence of true anaerobes. Such a retort, while suggestive, did not constitute an adequate reply to Gunning's experimental facts or to the essential theoretical point of his discussion. It gave an opportunity for a vigorous rejoinder, and Gunning seized the occasion for a very clear restatement of his observations. In this he even went so far as to say that, by sufficient removal of oxygen, food can be preserved without heat treatment. Needless to say, this proposal has never proved practicable.

Some years later Lachowicz and Necki continued the controversy by repeating Gunning's experiments with cultures of anaerobes and with attention to the specific points which Gunning had emphasized, using Gunning's reagent. They displaced the oxygen in their apparatus with a stream of hydrogen which did not color this reagent. The inoculation with a "strict anaerobe" was made through an opening through which a stream of this hydrogen was flowing. The products of fermentation were determined as proof that an extensive decomposition had occurred. The bacteriological examination showed abundant growth. If it be granted that the technique was good, the results of Lachowicz and Necki might be regarded as an adequate answer to Gunning. But throughout the history of the subject investigators have repeatedly given out statements essentially similar to Gunning's and based only upon an inherent tendency to demand that all life be supplied with molecular oxygen.

Among the subsequent investigations those of Fermi and Bassu were the most elaborate. But as Gunning had erred on the bacteriological side so Fermi and Bassu erred on the chemical side, displaying an abominable sense of chemical technique. Kürsteiner could not confirm them.

Finally Beijerinck made one of those delightfully *naïve* postulates that recur throughout the history of the subject. He said there can be no strict anaerobes, for every cell has its oxygen requirement, and this requirement is sometimes so small that it cannot be detected by the most refined chemical methods. Such a thesis is easy to defend because by definition it cannot be controverted by experiment.

But to be fair to Beijerinck we must briefly mention the important experimental basis of his deduction. He grew bacteria with limited oxygen supply, and found the so-called respiration figures of Englemann. So-called aerobes congregated nearest the oxygen supply; so-called anaerobes congregated furthest from the oxygen supply. But as the oxygen supply was lowered the so-called anaerobes migrated to a position intermediate between the most and the least oxygenated points. Fox obtained similar so-called respiration figures with a protozoon. Beijerinck also claimed to have shown that short exposure to oxygen is necessary for revivifying certain so-called anaerobic and facultative organisms. He therefore divided bacteria into aerophils—lovers of oxygen—and microaerophils—lovers of little oxygen. This philosophy permeates much of the subsequent literature and with results which are often amusing. A prominent pathologist uses the self contradictory term, "Aerotrophic anaerobe," and a bacteriologist writes, "*Clostridium welchii* is an obligate anaerobe which requires strict anaerobiosis for growth. All anaerobes, especially obligate anaerobes, have an optimum O_2 tension above which growth ceases."

Kürsteiner did not explain the respiration figures of Beijerinck but he did show rather conclusively that certain anaerobes can be carried through 16 inoculations involving numerous generations, all under anaerobic conditions and without impairment of function. For the assurance of the absence of oxygen in these experiments Kürsteiner used the luminescence of the luminescent bacteria. More recently Harvey has shown that the luminescence of these bacteria reveals the presence of one part of oxygen in 3,700,000,000 parts of water. There is now little doubt that bacteria as well as higher forms of life can grow without free oxygen.

In a paper published in 1911, Carl Snyder summarized much of the material I have so far mentioned, and set forth numerous reasons for the belief that the beginnings of life on our planet were anaerobic. Snyder reviews the arguments of Koene, Phipson, Lemberg, Stevenson, Lord Kelvin, and Arrhenius to the effect that our primitive atmosphere was devoid of free oxygen and that the oxygen we now find is that liberated from carbon dioxide by the action of that great plant life which laid down enormous deposits of coal. This plant life was anaerobic and depended for its energy upon sunlight; but with the development of an oxygen atmosphere there arose organisms feeding basically upon plant life, and taking advantage of the energy derived by combustion.

We are not concerned with Snyder's thesis, but rather with the experimental facts as we know them; and now let us return to our own metabolism.

In the introduction I mentioned the blood equilibrium, and the conditions under which oxygen is transported in the blood. What is the destiny of this oxygen in the working muscle?

In their Croonian Lecture, Fletcher and Hopkins made it clear that if the hydrogen ion concentration is maintained at a favorable point and if the products of activity are washed away, a muscle will continue to contract on stimulation in an atmosphere of nitrogen. Fundamentally the process is anaerobic. More recently A. V. Hill, by designing special galvanometers and special thermocouples capable of quickly responding to a rise of one-millionth of a degree Centigrade, has shown that when a muscle is excited by a short shock the immediate mechanical response is followed by a long period of heat production. This heat is due to an oxygen consumption. This oxidation Meyerhof has shown to be associated with a reconstruction of glycogen. It should be especially noted that it is a recovery process of comparative slowness and that the mechanical contraction is an anaerobic phase.

And so at last we have come to see in the muscle itself, that organ which we have always associated with an insistent oxygen demand, the primary anaerobic life displayed in purer form by the anaerobic bacteria.

Some 60 years ago Pasteur conceived of anaerobic and aerobic life as different manifestations of the elasticity of the cell in adapting itself to different conditions. But, because other problems were uppermost in men's minds, and chiefly because of the psychological tendency to extend our own external requirements to a dogma covering all life, the philosophy of anaerobiosis has had hard sledding.

In the arguments of those who insist upon the necessity of molecular oxygen are many fallacies. Undoubtedly the outstanding fault is psychological. This tendency of ours to dogmatize on our own requirements was characterized by Gautier as the great error of physiology. Writers have postulated oxygen reserves in so-called inogen molecules to account for growth without free oxygen. Winterstein has shown that there is not one experimental proof of this. Oxidation is postulated as a necessary source of energy, but even Beijerinck had to admit that the available quantity of oxygen is often too small to have any significance for energy supply, and he ascribed to it a function comparable with that of our present day

vitamines. In doing so he dwelt upon the fact that yeast seems to require rejuvenation by oxygen. Burri claims, with how much justification I do not know, that this is because oxygen is necessary to the yeast for zymase production, and has no general significance. When the zymase is once formed the yeast can live without air.

Sometimes the need of oxygen is postulated with such assurance that writers have said anaerobes tear oxygen from molecular combination and use it in combustion. Of course this is nonsense, but a much more reasonable postulate, and one difficult to handle, is that of intramolecular oxidation. With the exception of this, most of the discussion, as Duclaux said long ago, is mere guesswork. Lesser adds, "In no other field have theories been built so lightly without one experimental proof."

Let us neglect the futile discussions in the literature and return to experimental fact. We have already noted the efforts of bacteriologists to reduce the oxygen tension of the medium. Sometimes, however, oxygen absorbing agents of strictly chemical nature have been used in the culture media themselves. Whether consciously with this purpose, or not, various bacteriologists, at various times and independently, introduced living tissues which are known to absorb oxygen. One used a piece of liver, another a potato, another a germinating seed. When this was done the medium could be exposed to air and still the anaerobe would grow. Now these methods were regarded as new by their authors but in principle they differ in no essential respect from the principle discovered at the very first by Pasteur. He had wondered how anaerobes could exist in a world where oxygen tends to penetrate the habitat of every organism, and he had found a simple answer. In nature are mixed cultures of aerobes and anaerobes. The aerobes exhaust the oxygen and then the latent anaerobes develop. It is believed that the deadly anaerobe of tetanus cannot develop in a wound till aerobes have reduced the oxygen. So efficient is this effect of aerobes that Kedrowski claimed he found anaerobes growing in admixture with aerobes, even though air was bubbled through the culture. This experiment should be repeated because it is pregnant with significance.

Now it is a curious and significant fact that after all the laborious efforts to obtain anaerobic conditions mechanically or chemically and the observation that oxygen is definitely toxic to certain anaerobes, these organisms were found to be able to grow alone in certain simple media when exposed to the air if given an initial start. It was found that inert material such as asbestos, providing shelters in its inter-

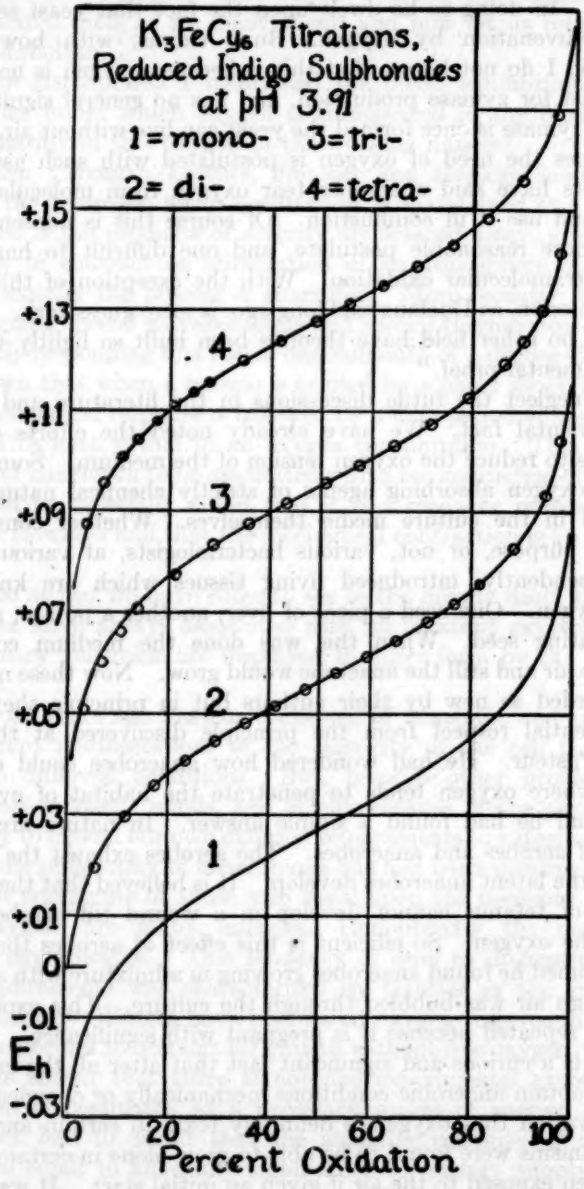

Fig. 1.—Change in electrode potential with oxidation of reduced indigo sulphonates.

stices, favored growth. There can be little question that this is due in part to the native ability of anaerobes to reduce their environment, and thus create their own anaerobiosis if not overtaxed.

In short, we are now tracing a profound similarity in principle among the diverse methods for anaerobiosis. First, there are methods for the mechanical removal of molecular oxygen; second, the chemical absorption of what is presumed to be molecular oxygen within the medium. Both prove the possibility of life without molecular oxygen. But finally we find the positive reducing action of the anaerobes themselves, and are led to believe that if this is not overtaxed anaerobes can produce their own anaerobiosis. Were the older methods after all merely assurances against overtaxing the reducing action of the anaerobes, and what is the significance of this reducing action? In the answer we shall find a new outlook upon many important problems.

From the time when Helmholtz demonstrated the reduction of litmus by bacteria there has been an immense amount work on biochemical reduction which I shall have no time to review. Various organs of plants and animals and the cells of the microscopic world, when isolated from the reversing effect of the oxygen amidst which our ordinary experimental work is done, tend to reduce with a decisiveness which has astonished many an investigator. In studies of this reducing tendency the tools of investigation have been mostly reducible dyes such as indigo carmine and methylene blue. Although the reduction of methylene blue by cells has been found almost universally and hence has been proposed as a test of life, there has been little understanding of the quantitative aspects of dye reduction and consequently a large amount of bizarre speculation.

We now know in terms of electrical potential the intensity conditions governing the reduction of these indicators of reduction.

I reported last year the work on this problem done in the Dairy Division and in the Hygienic Laboratory and shall review the data in the briefest possible way. A mixture of indigo carmine and leuco indigo carmine at constant hydrogen ion concentration (expressed in units of pH) gives a definite electrode potential difference. Graphically expressed (see figure 1), with electrode potential difference as ordinate and percentage reduction as abscissa, we have an $\int$-curve, the mid-point of which gives the characteristic of the system. The different sulphonates lie at different levels as shown in figure 1. Because reduction creates anions the system is sensitive to the hydrogen ion concentration of the solution. If we deal with the mid-point of

each curve as characteristic and carry this 50-50 mixture of oxidant and reductant to different values of pH, we shall obtain the positions of the system in a third dimension, that of pH. Figure 2 shows the experimental result. In short, we have experimentally determined

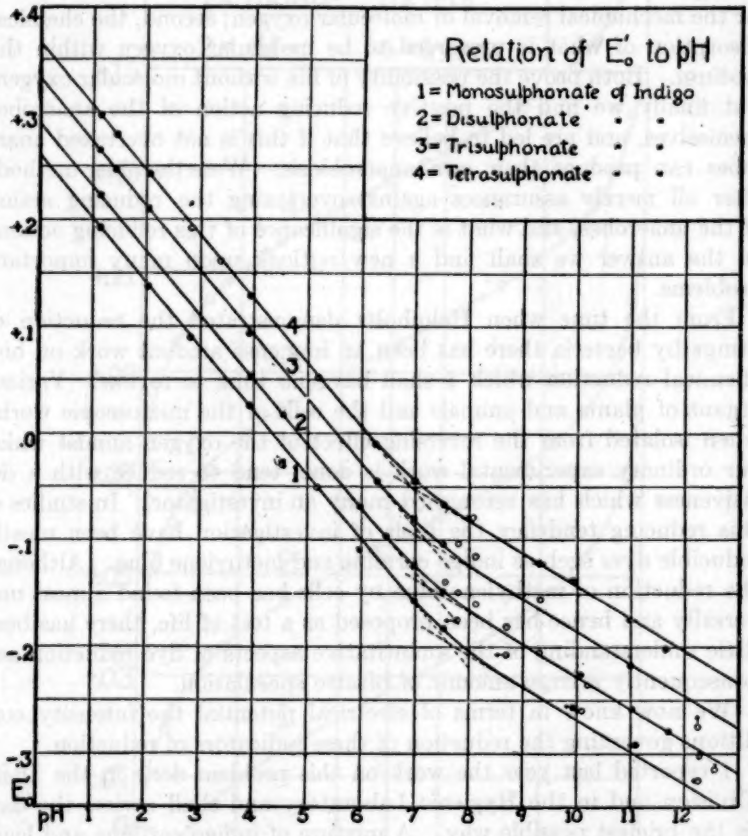

Fig. 2.—Relation of oxidation potential to pH for indigo sulphonates.

the reduction potentials or intensity conditions for the reduction of indigo carmine to any percentage reduction at any pH.

Let us now turn back to a scene in the French Academy on July 1, 1878. On that day Gunning presented his arguments against anaerobiosis. At the close of his remarks Pasteur rose to say that for 16 years he had been seriously concerned with the sources of error

noted by Gunning, and had concluded that his own cultures were free of molecular oxygen because indigo white remained reduced.

This statement we can now interpret. In aqueous solutions electrode potential differences such as those of the indigo system can be interpreted in terms of the oxyhydrogen gas cell. Now in figure 3 electrode potential differences are plotted as lower abscissa and pH values as ordinate. Assuming the potential difference at zero pH and one atmosphere, H_2, as an arbitrary zero point, the slanting line at the left on the chart, represents the variation with change of pH in the potential of a hydrogen electrode. The theoretical potential difference at an electrode under one atmosphere pressure of oxygen

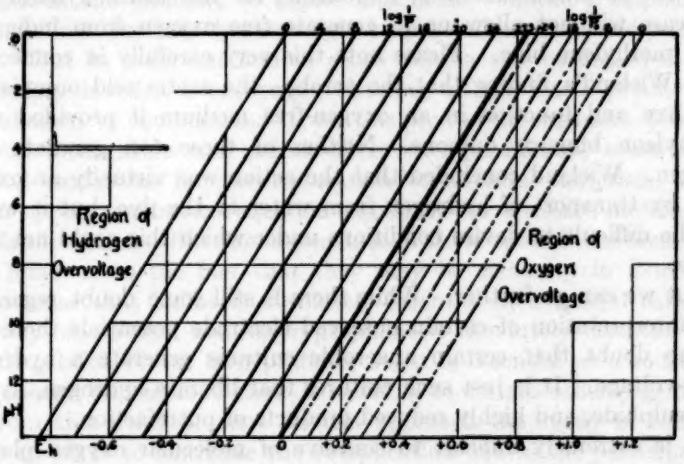

Fig. 3.—Relation of electrode potential to pH for systems of varying degree of oxidation.

is 1.23 volt more positive at all values of pH. The line of the oxygen electrode is, therefore, at the extreme right, parallel to the line of the hydrogen electrode with a constant difference of 1.23 volt between.

The intermediate lines show the relations for diminished hydrogen pressures on the one hand and diminished oxygen pressures on the other hand, at intervals of the 4th power of ten. Knowing the potential difference in terms of a hydrogen electrode and the pH, we can calculate for a partially reduced indigo solution the *hypothetical* hydrogen or oxygen pressures in equilibrium with the system. In a case where we allowed bacterial reduction of indigo carmine to proceed to 80 per cent reduction we measured the potential electrometrically

and calculated therefrom the oxygen pressure. It came out 10^{-36} atmospheric. Taking the data of Millikan on the number of molecules per gram mol of gas we calculate that less than one discrete individual molecule of oxygen was present *at equilibrium* in 10^{13} liters of the culture. To speak colloquially, that is *some* anaerobiosis.

Let it be carefully noted that this conclusion only says that there can be no appreciable oxygen in *equilibrium* with a reduced indigo solution. It does not say that oxygen, because of its inertness, may not remain if originally present. But if present under these circumstances the oxygen must be regarded as comparable to so much inert nitrogen. Even if this is pressing the point too far we must conclude that the reverse situation is impossible, for the thermodynamics of the case will not allow us to generate free oxygen from indigo or even methylene blue. Please note this very carefully in connection with Wieland's finding that the aerobe—the acetic acid organism—can live and function in an oxygen-free medium if provided with methylene blue or quinone. Neither of these can generate free oxygen. Wieland concluded that the action was virtually an oxidation by transport of hydrogen from water to the dye, but it would not be difficult to devise conditions under which this could not take place.

But we can go further. While there is still some doubt regarding the interpretation of certain observed electrode potentials there can be no doubt that certain anaerobic cultures generate a hydrogen over-voltage. It is just such cultures that liberate hydrogen, hydrogen sulphide, and highly reduced products of putrefaction.

It is extremely difficult to conceive of molecular oxygen playing any part in the activity of a cell that is producing a hydrogen over-voltage and tearing to pieces by reductive action materials which resist strong chemical reducing agents.

In short, the earlier debates, concerned as they were with oxygen tensions over the medium, were quite beside the point. The main problem is found in the oxidation-reduction equilibria within the medium. We have seen that life without oxygen is a fact among bacteria, protozoa, and a variety of low animals, but back of all this is an unexplored region.

And now let me ask a question. Are anaerobiosis and aerobiosis two different sorts of life? If they are we shall find difficulty in establishing unity among the myriad of adaptations to both forms of existence. Let it be remembered that the muscle can act in the presence of reduced methylene blue and the anaerobe *tetanus* can

grow in cultures exposed to air. What we find in general is the reducing tendency of the isolated cell; what we find in particular are special mechanisms for the use of molecular oxygen.

And special mechanisms are required, for oxygen is more or less inert. The prairie grass lies bleaching in the sun and dry, the forest leaves wither, our houses stand for centuries when no kindling temperature activates that stable doublet O_2. And life itself, as Meyerhof says, is never in equilibrium with this consuming element oxygen. To use it smoothly, life has evolved its special mechanisms. Beneath these lie more fundamental processes.

We need not detract at all from the true importance of molecular oxygen in the economy of higher organisms. Indeed I emphasized it in the introduction, that we might keep a well proportioned perspective. But in a certain limited sense oxygen can be regarded as a secondary invader, a scavenger, cleaning up the waste products of metabolism by combustion. If for this process the organism develops special mechanisms and seizes upon heat production, seizes upon special oxidations for the restoration of essential materials, seizes upon special oxidation-reduction equilibria for special functions, so much the better. But the importance of these special functions need not blind us to the fact that they may be accessory in much the same sense that iodine is absolutely essential in a special catalytic activity of our own bodies, tryptophane is absolutely essential as a building brick of our own proteins, sugar is essential as a source of our energy, and none of these is essential to certain other organisms.

From this point of view we can approach the study of the cell with an effort to eliminate the complication due to the participation of molecular oxygen. We shall then find a course unreversed by oxygenation.

In presenting this point of view I am conscious of an objection which will at once be raised. Every reduction implies an oxidation in the chemical sense. Granted that the molecular oxygen is absent, *intramolecular* oxidation is still possible. This is true as between specific bodies. Without molecular oxygen alcohol can still be oxidized biologically to acetic acid, and, what is often forgotten, something else must be reduced. But it is not this aspect with which we are concerned. It is simply that, having eliminated the reversing effect of molecular oxygen, we find the inherent ability of the cell to alter a closed system so that the over-all reduction intensity rises higher and higher. Redescription of the reciprocal intramolecular oxida-

tion-reduction between specific bodies does not explain the increase in general reduction intensity of the system.

In your contemplation of this experimental fact I would leave with you but one further conclusion, again based on experimental data. In studying the oxidation-reduction equilibria of dye solutions we find systems that can not be in equilibrium with appreciable quantities of hydrogen or oxygen. Quantitative determinations show that the hydrogens of the same system ionize at different intensity levels. On the other hand there is quantitative evidence proving to the hilt that whatever jumps between reductant and oxidant in the reversible transformation is a pair of electrochemical equivalents, each unit of which jumps between the same intensity levels as the other. There seems to be no interpretation of these experimental facts but the assumption of a direct transfer of an *electron pair*.

If we now examine critically the tests used in the exploration of biological reduction we shall find that they are for the most part colorimetric tests making use of dye-reduction. The solitary conclusion with experimental backing, regarding the mechanism of such reductions by life processes, is that cellular activity forces electrons into these dyes. What is the significance of this to our understanding of life?

As Goethe said, "We are not born to solve the problems of the world, but to find out where a problem begins and then to keep within the limits of our grasp."

The problem I have outlined I leave where the new problem begins. If we knew the answer ours would not be the zest of the pursuit.

BOTANY.—*New West Indian ferns.*[1] WILLIAM R. MAXON, National Museum.

Several collections from the West Indies, chiefly the Greater Antilles, in the last few years have added materially to our knowledge of the fern flora by extending the known range of species previously regarded as confined to one or more of the islands or to continental regions, and by bringing to light a considerable number of new species. Six of the latter are described herewith.

Cyathea brittoniana Maxon, sp. nov.

Caudex erect, 2.5 to 8 meters high; fronds erect-spreading, up to 3 meters long; stipes up to 12 mm. thick at base, ochraceous-olivaceous from a darker base, lustrous, glabrescent, thickly beset with slender straight pungent spines up to 1.5 mm. long, conspicuously paleaceous at base, the scales subulate-attenuate, about 3.5 cm. long, 2 mm. broad at base, rigid, straight, minutely erose-denticulate throughout, golden brown, highly lustrous; blades of an ovate type, abruptly short-acuminate, 2 meters long or more, 1 to 1.2 meters broad, subtripinnate, the rachis ochraceous-olivaceous, aculeolate or muricate, at first closely hirsutulous above, glabrescent, lustrous; pinnae alternate, subdistant, laxly spreading, stalked (1 to 3.5 cm.), linear-oblong, acuminate, 45 to 62 cm. long, 12 to 18 cm. broad, the secondary rachis strigose above, beneath distantly aculeolate or muricate, scantily and laxly hirsutulous, and bearing a few deciduous scales, these linear, up to 9 mm. long, tortuous, fimbriate-ciliate; pinnules 25 to 30 pairs below the tip, distant to approximate, mostly alternate and short-stalked (1 mm.), linear-oblong, 6 to 10 cm. long, 12 to 18 mm. broad, obliquely pinnatifid to about 1 mm. from the costa, the costa densely hirsute-strigose above with curved grayish hairs, beneath thinly hirsute and distantly paleaceous, the scales bright yellow-brown, mostly ovate and long-acuminate, 1 to 2.5 mm. long, slightly concave, asymmetrical or not, thin, lustrous, denticulate-ciliolate; segments 16 to 18 pairs below the tip, oblong, falcate, distally acutish, 3.5 to 4 mm. broad, close, parallel, crenate-serrate (deeply so toward the tip), the costule hispid above, beneath thinly hirsute and bearing a few small scales toward the base, these mostly bullate, bright yellowish brown, thin; veins 8 to 10 pairs, oblique, mostly once forked below the middle, prominulous and glabrous above, thinly hirsute beneath, the hairs extending to the leaf tissue; sori 3 to 5 pairs, small (about 0.7 mm. in diameter), slightly inframedial; indusium globose, membranous, transparent, rupturing irregularly, the divisions subpersistent; receptacle small, short-capitate; paraphyses numerous, short, flattish, flaccid, deciduous. Leaf tissue dull dark green, slightly paler beneath, delicately membranous.

Type in the U. S. National Herbarium, no. 755,722, collected in mountain forest, Mt. Alegrillo, Porto Rico, at 900 meters altitude, April 3, 1913, by N. L. Britton, F. L. Stevens, and W. E. Hess (no. 2620). Other specimens examined are as follows:

PORTO RICO: Maricao, July, 1913, *Hioram* 809.

CUBA: Monte de la Prenda, Oriente, altitude 800 meters, in forest, *Eggers* 5211. Pinal de Santa Ana, Oriente, altitude 800 meters, *Eggers* 5031.

[1] Published by permission of the Secretary of the Smithsonian Institution.

DOMINICAN Republic: Paradis, Barahona Province, at 450 meters altitude, *Abbott* 1590.

TRINIDAD: Without locality, *Fendler* 80 (3 sheets, as *C. schan-schin*). Mt. Tocuche, in forest, *Britton, Hazen & Mendelson* 1351.

Cyathea brittoniana is closely related to *C. tenera* (J. Sm.) Griseb., to which the material above described has been erroneously referred in recent years. That species, described originally from St. Vincent, is widely distributed in the West Indies. It differs from *C. brittoniana* in its darker and more strongly aculeate stipes (the spines fewer, up to 3 mm. long), its dilatate, less falcate, nearly obtuse segments (the sinuses broader), its more numerous bullate scales (these usually extending two-thirds the length of the costule), and its scant hirsutulous rather than hirsute condition beneath, the hairs inconspicuous, much shorter than in *C. brittoniana*, and rarely if ever extending to the leaf tissue. One other character is noted in the paraphyses, which are somewhat rigid, dark castaneous to vinaceous, and subpersistent, in contrast to those of *C. brittoniana*.

The following specimens of *C. tenera* are at hand:

ST. VINCENT: *H. H. Smith* 1717; *H. H. & G. W. Smith* 292; *Eggers* 6859.

GRENADA: *Elliott* 10; *Murray & Elliott* 10; *Sherring* 157, 228 (4 sheets).

MARTINIQUE: *Sieber* 374.

MARGARITA ISLAND (Venezuela): *Johnston* 143 (2 sheets).

TRINIDAD: Heights of Aripo, *Broadway* 9968 (2 sheets). Morne Bleu, *Britton, Freeman & Bailey* 2285.

CUBA: Loma San Juan, Sierra Maestra, altitude 1,050 meters, *Léon, Clement & Roca* 10535.

DOMINICAN REPUBLIC: Paradis, Barahona Province, altitude 600 meters, *Abbott* 1664.

Polypodium oxypholis Maxon, sp. nov.

Rhizome wide-creeping (15 cm. or more), 1 to 2 mm. in diameter, sinuous, green, emitting a few radicose rootlets at intervals, densely paleaceous at the growing tip (2 to 5 cm.), subpersistently so throughout, the scales dark brown, divaricate, 5 to 6 mm. long, evenly linear-attenuate from a deltoid-lanceolate deeply auriculate base, attached at the distant included sinus, rigid, subdentate, clathrate, the cells of the elongate portion narrowly oblong to linear-polygonal, with strongly sclerotic yellowish-brown partition walls, the outer walls thin and translucent. Fronds several, 1 to 2.5 cm. apart, 30 to 35 cm. long, ascending; phyllopodia small, 1.5 mm. high; stipes 11 to 17 cm. long, very slender (0.5 to 1 mm. thick), stramineous, naked; blades 17 to 22 cm. long, 2 to 3.5 cm. broad at middle, simple, varying from narrowly oblong-lanceolate to pointed-linear, long-acuminate or attenuate at base, caudate at apex (the tip about 3 cm. long, 5 mm. broad at base), repand, the margins unevenly sinuate; costa greenish-stramineous, elevated on both surfaces, 0.5 mm. broad or less; main veins 25 to 35 pairs, mostly alternate, diverging from the costa at an angle of 45° to 50°, elevated beneath nearly to the margin, flexuous, the connecting veins strongly arcuate; areoles mostly arranged in 4 series from costa to margin, variable in shape, size, and venation, the costal ones in the middle portion of the blade mostly obovate-cuneate, with a single included fertile veinlet; second and third areoles broader,

with 1 or 2 short included fertile veinlets, or one or both of these excurrent to the next cross-vein, or the areole divided by a median excurrent veinlet, the marginal areoles commonly so divided; sori in 4 irregular incomplete rows on either side the costa, appearing sparse; leaf tissue translucent, firmly pergamentaceous, sublustrous, the margins somewhat cartilaginous and narrowly revolute, the veins (primary ones excepted) immersed.

Type in the U. S. National Herbarium, no. 1,077,311, collected on a damp cliff of Morne de Ouésanne (Morne de Brouet), near Furcy, Haiti, altitude about 1,300 meters, June 13, 1920, by E. C. Leonard (no. 4782).

A peculiar species, without near relatives. In its slender stipes and slight, wide-creeping, divaricately paleaceous rhizomes only it suggests *P. vulpinum* Lindm.[2] a species which differs widely in its much smaller size, in shape of blade and in most details of venation, and in its rhizome scales, these thin, ferruginous, concolorus, and nonclathrate, the cells with all the walls thin and nonsclerotic. The relationship with *P. vexatum* D. C. Eaton is remote, that species having the rhizome short-creeping and much stouter (3 to 8 mm. thick), the rhizome scales thin, *orbicular-ovate*, *peltate*, and *closely appressed* to the rhizome, and the blades very strongly long-attenuate downward to the narrowly alate stipe. On the basis of scale characters alone the species may be distinguished at a glance.

Stenochlaena amydrophlebia Slosson, sp. nov.

Rhizome flat, woody, 12 mm. broad, densely paleaceous at the produced tip, the scales bright russet brown, lance-attenuate, 6 to 9 mm. long, about 1.5 mm. broad, very lax, membranous, denticulate and bearing very long filament-like gland-tipped teeth. Sterile frond 70 cm. long; stipe 25 cm. long, dull brown, finely paleaceous in the basal part; blade lance-oblong, obtuse, 45 cm. long, 14 cm. broad near the middle, pinnate, the rachis strongly foliaceo-marginate; pinnae 16 or 17 on each side, alternate, distant (inserted 2 to 3 cm. apart on each side), linear, 6 to 9 cm. long, 10 to 13 mm. broad, narrowly cuneate at the inequilateral base, rather abruptly short-caudate at apex (the tip 5 to 7 mm. long, 1 to 2 mm. broad, blunt), oblique, straight or subfalcate, subentire or at apex sinuate-dentate, glabrous above; apical pinna conform; midvein broad and obtusely sulcate above, beneath minutely and obscurely paleaceous at the elevated base, a few very minute substellate scales extending to the veins and leaf issue; veins close, slightly oblique, mostly once forked near the base, deeply immersed, concealed above, their course barely evident beneath; leaf tissue coriaceous, dull green above, a little paler or somewhat yellowish green beneath. Fertile frond 63 cm. long; stipe 22 cm. long; blade lanceolate, 41 cm. long, about 10 cm. broad below the middle, the rachis deciduously fibrillose; pinnae about 16 pairs, alternate, distant, oblique, linear, mostly 4 to 7 cm. long, 2 mm. broad, substipitate; spores minutely papillose.

Type in the Underwood Fern Herbarium, New York Botanical Garden, collected in dense forest, Río Icaco and adjacent hills, Sierra de Naguabo, Porto Rico, altitude 465 to 720 meters, July 30 to August 5, 1914, by J. A. Shafer (no. 3510a); fragments are in the U. S. National Herbarium, no.

[2] Described from Brazil and now known from numerous Haitian specimens (Furcy, *Leonard* 4287, 4638, 4721, 4778; Mission, *Leonard* 4010, 4024.

694,686. Other Porto Rican specimens are a sterile unnumbered Sintenis plant, without special locality data, and two juvenile plants collected in the Sierra de Naguabo by Britton and Hess (no. 2294) at an altitude of 950 meters. Received recently also from the Dominican Republic (*Fuertes* 1044c), the specimens fertile and entirely characteristic.

A well marked species, related apparently to *Stenochlaena wrightii* (Mett.) Griseb, of eastern Cuba (*Wright* 787; *Maxon* 4300, 4481; *Shafer* 8833; *Léon, Clement & Roca* 10385; *Hioram & Maurel* 2484; *Pollard & Palmer* 150; *Pollard, Palmer & Palmer* 220). That species, however, differs conspicuously in its sterile fronds, the pinnae (5 to 10 pairs) being obovate to oblong-oblanceolate, 1.5 to 3 cm. broad, and abruptly truncate below the long-caudate apex.

Dryopteris petiolata Maxon, sp. nov.

Subgenus *Goniopteris*. Rhizome woody, decumbent, apparently 5 or 6 cm. long, about 2 cm. thick, densely paleaceous at apex, the scales imbricate-spreading, linear-attenuate, 9 to 11 mm. long, 2 mm. broad at base, bright brown, thin, lustrous, entire, laxly stellate-puberulent. Fronds several, subfasciculate, 65 to 85 cm. long, suberect; stipes 30 to 45 cm. long, stramineous, deeply sulcate at the strongly arcuate darker base, naked, deciduously stellate-pubescent, lustrous; blades lance-oblong, evenly acuminate at tip, scarcely or not at all reduced at base, 35 to 45 cm. long, 15 to 20 cm. broad, pinnate, the rachis similar to the stipe, devoid of simple hairs; pinnae 12 to 15 pairs below the tip, spreading nearly at a right angle, distant, subopposite to alternate, mostly stalked (1 to 3 mm.), the lower ones narrowly linear-lanceolate, those above nearly linear, mostly 8 to 10 cm. long, 12 to 17 mm. broad, all but the upper ones pinnatifid nearly half-way to the costa except at the attenuate subcaudate tips, these 1.5 to 2.5 cm. long, subentire; costae elevated beneath, scantily and deciduously hirsutulous, stramineous, persistently stellate-pubescent, stellate hairs extending also to the prominulous veins and sparingly to the leaf tissue of both surfaces; segments about 18 pairs, slightly oblique, rounded-triangular, mostly a little longer than broad, the margins entire, slightly revolute, beset with numerous short oblique rigid cilia; veins 6 to 8 pairs, simple, close, the basal ones joined, the resultant veinlet and the second or second and third veins excurrent to sinus; sori strongly inframedial, large (nearly 1.5 mm. in diameter), round, close, forming a dense row almost against the costule; indusia minute, deterg-ible, consisting of several connate branched hairs; sporangia very numerous, nonsetose.

Type in the U. S. National Herbarium, no. 1,145,848, collected on steep mountain slope near Liali, Dominican Republic, at 400 to 500 meters altitude, February 9, 1923, by W. L. Abbott (no. 2596). A second specimen of the same number is mounted on sheet no. 1,145,791.

Because of its general leaf-form and stalked pinnae *D. petiolata* is to be compared with *Dryopteris pyramidata* (Fée) Maxon, which also occurs in the eastern part of the Dominican Republic and is not uncommon in the Lesser Antilles southward to the Guianas. That species differs not only in its triangular blades and in having one or several pairs of the lower pinnae reduced at the base, but very materially also in its more oblique and more numerous veins (these usually connivent only), in its freely pilose-hirsute

rachis and costae (similar but minute simple hairs extending to the costules and veins), and in having the sori medial and distinctly indusiate, the indusia small but firm and persistent, with numerous simple marginal hairs. In *D. petiolata* a few simple hairs are found upon the costae, but all other vascular parts (including the rachis) are stellate-pubescent only, the branched hairs coarse and readily seen; whereas in *D. pyramidata* simple hairs predomiate throughout, the stellate pubescence being obscure and exceedingly minute. The indusial characters are equally distinctive.

Dryopteris aripensis C. Chr. & Maxon, sp. nov.

Rhizome not seen; stipe brown, 30 cm. long, 7 mm. thick at base, flexuous, trisulcate above, flattish-angulate, densely paleaceous toward the base the scales linear-attenuate, 7 to 13 mm. long, about 0.3 mm. broad at base, flexuous, denticulate-ciliate, bright cinnamomeous, similar but reduced darker scales extending upward to the rachis; blade ovate-oblong, acuminate, about 70 cm. long, 35 to 40 cm. broad, bipinnate, the rachis villous-pilosulous above with pluricellular hairs, beneath persistently paleaceous, the scales linear-attenuate, dark brown, subentire or distantly denticulate; pinnae about 20 pairs, the lower ones short-stalked (5 mm.), opposite, the others mostly subsessile, alternate, subdistant, all equilateral, linear-oblong, long-acuminate, the third or fourth pair the largest, 18 to 20 cm. long, 4 cm. broad, fully pinnate nearly throughout, the costa densely hirsute above with long oblique flattish white septate hairs, beneath scantily paleaceous, the scales brown, subulate-attenuate, denticulate, spreading; pinnules about 20 pairs, slightly oblique, the largest ones 2 cm. long, 7 to 8 mm. broad, the basal ones sometimes a little shortened, the others subequal, fully adnate and slightly decurrent, oblong, broadly rounded at apex (the smaller ones nearly truncate), straight or subfalcate, crenate-serrate to obliquely lobed one-third the distance to the costule, the lobes about 5 pairs, persistently short-ciliate; costules thinly long-hirsute above (the hairs about 1.5 mm. long, extending freely to the veins), sparsely hirsute beneath; veins 6 to 8 pairs, mostly once-forked, or the larger lobes with 2 pairs of subpinnately arranged branches, not reaching the margin, glabrous beneath; sori 2 or 3 to each group of veinlets, inframedial, nonindusiate. Leaf tissue dark green above, membrano-herbaceous.

Type in the U. S. National Herbarium, no. 1,059,366, collected on the Heights of Aripo, Trinidad, in forest, March 16, 1921, by N. L. Britton and W. G. Freeman (no. 2349). A second sheet of the same number has yielded data as to stipe and basal scales, and there are besides two other collections from the same locality: *Broadway* 9965 and *Britton & Freeman* 2352, these less developed.

Dryopteris aripensis belongs to the subgenus *Ctenitis*, group *Subincisae*, and is nearest related to *D. haitiensis* (Brause) Urban & Maxon,[3] both differing from *D. subincisa* in their small, narrow, bipinnate blades. In *D. aripensis* all the pinnae are narrowly oblong and essentially equilateral, the basal ones sometimes a little shorter than those above; in *D. haitiensis* the middle pinnae are triangular-oblong and nearly equilateral, and the basal pinnae short, triangular, and inequilateral; in *D. subincisa* the basal pinnae

[3] Journ. Wash. Acad. Sci. 14: 91. 1924.

are much the largest of all, compound, and strongly produced basicopically. From *D. haitiensis* the present species differs in the form of its pinnae, as just mentioned, it its more numerous, close, subequal, less deeply pinnatifid pinnules, in its thin texture, and in numerous details of scale structure and pubescence, the costules and veins of *D. haitiensis*, for example, entirely lacking the numerous, very long, stiff, white, septate hairs characterizing the same parts of *D. aripensis*.

Leptochilus pergamentaceus Maxon, sp. nov.

Plants terrestrial. Rhizome woody, horizontal, creeping, relatively slender (4 to 8 mm. thick), terete or flattish, brown, closely brownish-paleaceous; fronds few, erect, subdistant. Sterile fronds up to 1 meter long or more; stipes about as long as the blades, stout, trisulcate above, stramineous from a darker fibrillose-paleaceous base; blades broadly ovate-oblong, acuminate, 40 to 60 cm. long, 25 to 45 cm. broad, simply pinnate, the rachis stout, stramineous; pinnae mostly 2 to 5 pairs and a large terminal one, alternate, oblique, ovate, lance-ovate, or broadly oblong, acuminate to acuminate-caudate (sometimes abruptly so), mostly inequilateral and subfalcate, somewhat rounded or broadly cuneate at base (the lower ones distinctly stalked), more or less repand, the margins entire or broadly sinuate; lateral veins oblique (55°), decurved at extreme base, falcate, strongly elevated almost to the margin, here upwardly arcuate; transverse veins 8 to 10 pairs, elevated, deeply arcuate; areoles mostly shorter than broad, copiously reticulate, the ultimate meshes numerous, minute, mostly with 1 or 2 free included veinlets; leaf tissue firmly pergamentaceous, glabrous, usually light green, paler beneath. Fertile fronds up to 1 meter long, long-stipitate; pinnae 2 to 4 pairs and a larger terminal one, distant, oblique, lanceolate to narrowly oblong-lanceolate, acuminate, up to 15 cm. long and 4 cm. broad, densely sporangiate, the costae excepted; sporangia glabrous, the annulus 14-celled; spores very broadly and delicately winged.

Type in the U. S. National Herbarium, nos. 521,264 and 521,265, sterile and fertile fronds respectively, collected at Green River Valley, Jamaica, altitude 750 meters, February 11, 1903, by L. M. Underwood (no. 1426). Other specimens at hand are as follows:

JAMAICA: Several localities, *Underwood* 123; *Maxon* 1841, 1951, 2380; *Maxon & Killip* 550, 805; *Hart* 111; *Clute* 283; *A. Moore*.

CUBA: Several localities, *Wright* 788 (4 sheets); *Maxon* 3908, 4164; *Van Hermann* 3203; *Pollard & Palmer* 164; *Britton & Britton* 5002; *Hioram & Maurel* 2444.

PORTO RICO: Several localities, *Sintenis* 6534; *Shafer* 3790; *E. G. Britton* 5217; *Britton, Cowell & Brown* 5258; *Britton, Britton & Brown* 6177.

DOMINICAN REPUBLIC: Laguna, *Abbott* 378. Puerto Frances, *Abbott* 1205. Paradis, *Abbott* 1598. Liali, *Abbott* 2632.

GUATEMALA: Cubilquitz, *Türckheim* (J. D. Smith, no. 8045).

COSTA RICA: Without locality, *Wercklé*.

VENEZUELA: Upper Guaremales, road from Puerto Cabello to San Felipe, *Pittier* 9108.

As a result of recent study of the material passing as *Leptochilus nicotianaefolius* (Swartz) C. Chr. it becomes necessary to recognize two species of close relationship. These were long ago distinguished by Fée[4] as *Gymnopteris*

[4] Mém. Foug. 2: 85, 86. *pl. 46*. 1845.

nicotianaefolia Presl and *G. acuminata* Fée, the latter a transfer of *Acrostichum acuminatum* Willd. (1810), which was founded on a sterile specimen from "Peru" and upon Plumier's illustration of a Martinique plant (*pl. 115*). Unfortunately Fée, following Willdenow and Presl, applied the name *Acrostichum nicotianaefolium* Swartz in a wrong sense. This species had been described from St. Thomas in 1806. The original specimen is an atypical intermediate frond of five pinnae, the terminal pinna and two upon one side being small and fertile, the other two lateral ones large and sterile—an obvious monstrosity, such as occasionally develops in many species with dimorphic fronds. Several photographs of the type have been received from Stockholm through the kindness of Prof. C. A. M. Lindman. Not only in leaf shape but in details of venation these show essential agreement of the St. Thomas plant with Fée's description and illustration of *G. acuminata*, based upon material from Martinique and Guadeloupe and a single specimen from Jamaica. *Gymnopteris acuminata* (Willd.) Presl is thus a synonym of *Leptochilus nicotianaefolius* (Swartz) C. Chr. If regarded as based upon Plumier's plate 115, *Acrostichum acuminatum* Willd. also is synonymous; the identification of the Peruvian specimen cited by Willdenow remains in doubt. The Cuban plant (*Linden* 2117) which Fée describes as *G. nicotianaefolia*, and of which he gives a folio illustration, belongs to the species described above as *L. pergamentaceus*.

The distinctions between the two species are for the most part clear and have been partly stated by Fée. Thus, true *L. nicotianaefolius* (*G. acuminata* Fée) is usually epiphytic, climbing at the base of trees or sometimes on rocks; the pinnae of the sterile fronds are mostly stalked, straight and equilateral, and are usually elliptic-oval or narrowly pointed-oblong, the margins rather strongly sinuate; the lateral veins are less elevated and do not approach close to the margin; the transverse veins are much less deeply arcuate; the ultimate areoles are very much larger, many of them without included veinlets; and the leaf texture is membranous, not pergamentaceous, the ultimate venation prominulous.

Leptochilus nicotianaefolius widely overlaps *L. pergamentaceus* in range. In Jamaica it has been described as *Acrostichum nicotianaefolium* var. *saxicolum* Jenman.[5] The plant that Jenman describes as the typical form of *nicotianaefolium* is *L. pergamentaceus*.

Of *L. nicotianaefolius* the following material is in the National Herbarium:

MARTINIQUE: *Duss* 1699.
GUADELOUPE: *Duss* 4145.
ST. THOMAS: Photographs of the type, *ex herb. Swartz*.
PORTO RICO: Near Mayaguez, *Britton & Marble* 634.
DOMINICAN REPUBLIC: Cotuy, *Abbott* 822. Paradis, *Türckheim* 2822.
JAMAICA: Seamen's Valley, Portland, *Maxon & Killip* 40.
GUATEMALA: Cubilquitz, Alta Verapaz, *Türckheim* (J. D. Smith, no. 8829).

[5] Bull. Bot. Dept. Jamaica, n. s. 5: 153. 1898.

SCIENTIFIC NOTES AND NEWS

The following communication has been received from Dr. David Starr Jordan, Stanford University, California:

"The recent burning of the great Library of the Imperial University of Tokyo (with 500,000 to 700,000 volumes) is in itself a world calamity. I learn that the American Universities, Law Schools, and many City Libraries have given very generously of their publications, and of duplicates. Much has also been received from private sources. The chief deficiencies at present, are in scientific lines: Medicine, Physics, Chemistry, Biology, Mathematics and Engineering. At the request of Japanese friends, I make a special appeal to associations and workers in Science for donations of books and serials of scientific value.

Shipments will be received and transported free at the following addresses: Toyo Kisen Kaisha (T. Komatsu), 557 Market St., San Francisco, Calif; Mr. Aneha, care Hopkins Company, 18 Old Slip, New York City; Nippon Yusen Kaisha, Colman Bldg., Seattle, Wash.; Osaka Shosen Kaisha, Steel Steamship Co., Whitney Bldg., New Orleans, La."

The program for the meeting of the Washington Section of the American Chemical Society held February 14 was as follows: A. L. DAY: *The inter-relation of field and laboratory work.* E. T. ALLEN: *Field methods in the study of volcanology.* R. W. G. WYCKOFF: *Application of X-rays to the study of geophysics.* G. W. MOREY: *Experimental methods for the study of silicates at high temperatures, with demonstration of quenching a silicate melt.*

Dr. A. S. HITCHCOCK, agrostologist of the Department of Agriculture, returned last month from South America. Dr. Hitchcock visited Ecuador, Bolivia, and Peru, making extensive botanical collections.

GERRIT S. MILLER, JR., curator, Division of Mammals, National Museum, left Washington last month for a visit to some of the islands of the Lesser Antilles. Mr. Miller expects to make collections of the flora and fauna of the islands.

W. S. W. KEW, geologist of the U. S. Geological Survey, engaged in the study of the oil fields of Southern California, has resigned to do private work.

The Petrologists' Club met at the home of H. G. Ferguson on February 20. The evening was devoted to a discussion of corundum (crystalline alumina). W. L. BOWEN spoke on *Corundum in silicate melts;* H. INSLEY, on *Artificial contact metamorphic deposits;* and F. E. WRIGHT, on *Corundum in Africa.*

The Pick and Hammer Club met February 23, 1924, at the Geological Survey, addresses being made by speakers from the Carnegie Institution. Program: L. A. BAUER: *The geological bearing of investigations in terrestrial magnetism;* A. L. DAY: *The volcanic action at Lassen Peak;* E. T. ALLEN: *The hot springs at Lassen Peak;* H. S. WASHINGTON: *The chemical constitution of the Earth.*

A series of three lectures entitled *Some high lights of visual psycho-physics* will be given at the Physics Club of the Bureau of Standards by I. G. PRIEST in the Chemistry Building, at 4:30, as follows: March 24, *The classification and nomenclature of colors;* March 31, *general review of the leading principles of visual psycho-physics;* April 7, *Equivalent stimuli and relations deduced from the laws of mixture of stimuli.*